

**BROOKHAVEN NATIONAL LABORATORY**

# **OCCUPATIONAL HEALTH AND SAFETY GUIDE**

<b>FLAMMABLE CRYOGENIC LIQUIDS</b>	<b>5.2.0</b>
------------------------------------	--------------

## **I. INTRODUCTION**

This Guide is concerned with the safe use of liquid hydrogen (including deuterium) and liquid oxygen. Although the latter is considered to be inherently nonflammable it may combine with organic materials causing energetic reactions to occur. In addition to the usual hazards associated with cryogenics, such as explosive pressure releases, asphyxiation, and frostbite, these fluids in their gaseous state exhibit extremely high fire and explosion hazards. Gaseous hydrogen can form an explosive mixture over a range of 4 to 75% concentration in air. Gaseous oxygen has a much greater capacity for supporting combustion than air.

## **II. SCOPE**

This Guide sets forth requirements and procedures to minimize the possibility of fire or explosion resulting from the use of liquid hydrogen (LH<sub>2</sub>) and liquid oxygen (LOX). The guidelines for control of cryogenic hazards of these fluids are found in OH&S Guide 5.1.0, "Nonflammable Cryogenic Liquids." In general, safety requirements for flammable gases are found in OH&S Guide 4.12.0, "Locations Containing Flammable Atmospheres." Additional safety requirements and procedures for utilizing LH<sub>2</sub> and LOX are covered in this Guide. This Guide is generally limited to the safety aspects of engineered systems that are subject to the Cryogenic Safety Committee (CSC) review.

## **III. RESPONSIBILITIES**

**A. Department Chairmen/Division Heads** are responsible for ensuring that the requirements of this Guide are implemented in their areas of jurisdiction.

**B. Supervisors** are responsible for ensuring the direct implementation of this Guide for all activities involving flammable cryogenic fluids under their control. Specifically they shall:

1. Ensure that all designs for flammable cryogenic systems for proposed installations within their jurisdiction are submitted in document form by the designer to the Cryogenic Safety Committee as required by this Guide (see Section IV-A).
2. Ensure that all personnel involved in this activity are aware of the requirements of this Guide, are properly trained and wear personal protection equipment when required.
3. Ensure that cryogenic equipment operators are trained and qualified as described in Section V-E.
4. Ensure that adequate operating procedures are documented and records are maintained as required.

**C. Accelerator Department Liaison Engineers/Facility Manager** (in other departments) are responsible for processing a request for review of new or modified flammable cryogenic systems in their jurisdiction through the Safety and Environmental Protection Division Representative, prior to the introduction of flammable cryogenics in the system. They shall also assist in obtaining CSC design reviews when the proposal originates outside of BNL.

**D. Safety and Environmental Protection Division** is responsible for assisting in the implementation of this Guide. Specifically the **S&EP** Division shall:

## 5.2.0

1. Coordinate the environmental safety review of new and modified flammable cryogenic liquid installations and issue Safety Review Stickers (see Appendix A).
2. Audit departmental programs for compliance with this Guide.

E. **Accelerator Department Cryogenic Target Group** has the responsibility for being the sole receiver of flammable cryogenic fluid delivered to the site and limiting delivery of these fluids to those facilities cited in Section IV-A. They are also responsible for maintaining storage and delivery Dewars.

F. **The Cryogenic Safety Committee** is responsible for the review of documented designs of flammable cryogenic systems presented by the designers to the committee at a meeting as outlined in the Safety Policy Manual. Recommendations shall be forwarded to the Associate Director for Safety.

G. **The E.A.G. Watch (Accelerator Department)/Facility Manager** (other departments) is responsible for providing for the continuous surveillance of flammable cryogenic liquid system operations.

### IV. REQUIRED REVIEWS AND PROCEDURES FOR THE ADMISSION AND MAINTENANCE OF FLAMMABLE CRYOGENIC FLUIDS IN EXPERIMENTAL AREAS

A. All newly proposed flammable cryogenic liquid system designs shall be submitted in document form by the Project Supervisor or designer to the Cryogenic Safety Committee for review of both the equipment design and the integration within a building or laboratory. When previously CSC-reviewed equipment is put back in service in the original or slightly modified condition, the review may be limited to a CSC subcommittee.

After receiving a review by the CSC, and approval by the Associate Director for Safety, construction and installation may continue to completion. A facility for testing cryogenic equipment safely is maintained by the Accelerator Department Target Group.

A review of the completed floor installation prior to the admission of flammable cryogenic liquid shall be requested by the responsible person within the department through the Safety and Environmental Protection Division Representative. This review, which shall not be completed without the issuance of a **S&EP** Environmental Review Sticker, will verify compliance with CSC recommendations and this Guide (see Appendix A).

B. The presence of flammable cryogenic fluids in experimental areas shall be closely controlled by the Accelerator Department Cryogenic Target Group by limiting deliveries only to those areas designated by the CSC. Qualified personnel designated by the cryogenic supervisor shall be available to receive, store, and dispense these fluids safely. The requirements for on site transportation of flammable **cryogens** are given in Section VII.

C. In order to assure that the liquid hydrogen delivered to BNL is sufficiently pure to be utilized safely, the contents of all shipments shall be certified by the vendor to meet the specification of MIL-P-27201, Propellant, Hydrogen, DOD 1971 (Liquid Propellant Fuels and Oxidizers, Chemical Base).

D. Purchase orders for liquid oxygen shall specify the purity of the delivered product. Vendor shall certify that purchase order specifications are met.

### V. GENERAL PRECAUTIONS FOR LIQUID HYDROGEN AREAS

A. All storage tanks, portable Dewars, equipment, and systems used in handling liquid hydrogen shall meet the requirements of National Fire Protection Association Standard No. **50B**, "Liquefied Hydrogen Systems at Consumer Sites."

#### B. Liquid Hydrogen Area Safety

1. Venting to atmosphere shall never be to within a building but shall be via piping to the outside. Normal boil-off venting systems upstream of pressure relief devices shall be maintained at pressures slightly above atmospheric to minimize infiltration of air. Emergency venting systems need not meet this requirement but shall be separate from the normal venting (boil-off) systems. Liquid hydrogen shall not be used in unvented spaces. Positive air flow shall be maintained to ensure adequate air change minimizing stagnation or collection within the space.

2. Potential ignition sources shall be identified, and evaluated. These sources shall be eliminated whenever it is practical. Refer to OH&S Guide 4.12.0 for recommended electrical safety design. No smoking or open flames within a radius of 50 feet shall be permitted.
3. Portable combustible gas detectors shall be utilized for checking points not readily accessible or not monitored by stationary sampling heads.

#### C. Building Requirements

1. The building or room in which LH2 is to be used shall meet the electrical safety design requirements outlined in OH&S Guide 4.12.0.
2. When a temporary structure, such as a tent, is installed inside of a building to enclose LH2 equipment, that enclosure shall be continuously monitored by a combustible gas detector system. In the event of gas detection (at 25% of LEL), local audible alarms, remote watch station alarm indication, increased air flow ventilation, and the de-energizing of any ignition sources shall be initiated automatically. The emergency systems shall all be tested prior to start-up and must be in proper operating condition when LH2 is being used. The detecting system shall have the capability of being checked from outside the enclosure and holding a calibration of 25% of the LEL (LEL of hydrogen gas is 4%).
3. The area within a radius of 10 feet of LH2 equipment shall be kept free of combustible materials. In particular, solvents and other flammable fluids shall be properly stored away from the equipment.
4. The area shall have limited access, and signs indicating hydrogen is in use shall be prominently displayed. Exclude all unauthorized persons from the area.
5. The safest route for moving Dewars between the LH2 Dewar enclosure and a building exit shall be clearly marked and kept free of obstructions. An additional route for personnel access and egress shall be provided.

#### D. Equipment

1. All equipment designed for liquid H2 except certain Dewars shall have a normal boil-off vent and an emergency vent. Normal boil-off vents shall be maintained at slightly above atmospheric pressure to prevent back diffusion of air and plugs in the vent. The emergency vent shall contain a positive pressure relief device which will prevent rupture of the LH2 container. Vacuum insulated equipment and pumps shall be provided with pressure reliefs, that are vented to the outdoors.
2. All controls shall be connected to an emergency power circuit.
3. The equipment shall be electrically grounded. Any Dewar or transfer device shall then be electrically bonded to the equipment before transfer. First electrical contact with an H2 container shall be made away from any vent opening.
4. Dewars shall be protected from back diffusion and plugs by a check valve or other devices which will ensure a slight positive pressure in the vent spaces. They shall be connected to a normal boil-off vent to the outdoors, when not connected to equipment. They shall be checked daily to ensure proper venting. **Open-mouthed and/or glass Dewars shall not be used.**

#### E. Operation of Equipment

1. Unless specifically exempted by the Cryogenic Safety Committee, equipment containing LH2 shall be monitored by at least one qualified operator while the equipment has any liquid or gas in it, and until it has been completely emptied and purged. The operator shall be able to communicate with the shift supervisor or Department representative having emergency responsibilities.
2. A person is designated a qualified cryogenic equipment operator by the person's supervisor upon completion of required training and after demonstrating the capability of safe system operation. Some of the areas of knowledge required before designation are:
  - a. Properties and hazards of liquefied gases
  - b. Equipment safety systems

## 5.2.0

- c. Building safety systems
  - d. Appropriate Guides in the BNL Safety Manual
  - e. Local departmental operating and safety procedures
3. Before the introduction of H<sub>2</sub> into any system, the system shall be purged with inert gas and/or evacuated to remove air. This shall be repeated to ensure that no explosive mixture remains. When it is necessary to open the system to atmosphere, it shall first be purged to ensure that the resulting **H<sub>2</sub>-air** concentration is less than 1% H<sub>2</sub>. Detailed procedures for purging will differ with different systems. Exact written procedures for this operation shall be developed by the using department.

## VI. OPERATING REGULATIONS FOR LIQUID OXYGEN

### A. General Precautions for Liquid Oxygen Areas

1. Liquid oxygen has a much greater capacity to support combustion than has air. Porous organic materials, such as clothing or wood, may retain oxygen for a considerable period of time. They shall not be exposed to any source of ignition since they can burn violently. Mixtures of organic materials and LOX, under certain conditions, may detonate. Certain inorganic structural materials in contact with LOX can reduce the safety of the apparatus.
2. Before introducing LOX into a system, special precautions shall be taken to assure that all contaminants have been removed. The procedures given in the Compressed Gas Association Pamphlet, G-4.1 "Cleaning Equipment for Oxygen Service," shall be followed.
3. Identify all potential ignition sources and **eliminate** as many as possible within practical limits. Electrical equipment shall meet the same explosion proof requirements as those for LH<sub>2</sub>.
4. Oxygen analyzers shall be utilized for checking O<sub>2</sub> concentration and detecting leaks.

### B. Equipment

All equipment designed for utilizing LOX shall not have any materials of the type mentioned above (VI.A.1) in contact with LOX. The equipment shall be electrically grounded. Any Dewar or transfer device shall then be electrically grounded to the equipment before transfer. First electrical contact with any LOX container shall be made away from any vent opening.

### C. Building Requirements

See Paragraph V.C. covering LH<sub>2</sub>.

### D. Operation of Equipment

See Paragraph V.E. covering LH<sub>2</sub>.

### E. Safety Standards

The National Fire Protection Association Standard No. 50, "Bulk Oxygen Systems" and the Factory Mutual Loss Prevention Data Sheet 7-52 "Oxygen" have applicable requirements for the safe handling of oxygen.

## VII. TRANSPORTATION OF FLAMMABLE CRYOGENIC LIQUID CONTAINERS

- A. Liquid H<sub>2</sub> shall be transported only in containers designed for the purpose. These containers must be clearly marked "Hydrogen Flammable."
- B. All liquid H<sub>2</sub> trailers shall be provided with "Hydrogen Flammable" marking, reflectors, and safety tow chains, properly secured.
- C. All transportation of liquid H<sub>2</sub> and LOX over Laboratory roads shall be made during off-peak traffic periods by Accelerator Department Cryogenic Target Group personnel, using a truck equipped with a flashing yellow light. (For deliveries to and from the BNL site other standards apply.)
- D. Equipment used for storage and delivery of liquid H<sub>2</sub> shall be maintained by the Accelerator Department Cryogenic Target Group.

## APPENDIX A

<b>SAFETY REVIEW NO.</b> _____
SAFETY ASPECTS OF THIS APPARATUS WERE REVIEWED BY _____ & _____ ON _____ DETAILS OF RECOMMENDATIONS MADE ARE COVERED IN MEMO _____ TO _____ DATED _____ .
1. ANY SUBSEQUENT CHANGES IN CONTENTS, PRESSURES, TEMPERATURES, VALV- ING, ETC., WHICH <b>AFFECT</b> THE SAFETY OF THIS DEVICE REQUIRE ANOTHER REVIEW.
2. THE EXPERIMENTER MUST FAMILIARIZE HIMSELF WITH THE SAFETY AND <b>EMER-</b> GENCY PROCEDURES OF THE DEPARTMENT IN WHICH HE IS OPERATING THE DEVICE.
THIS FORM BY B. N. L. SAFETY & ENVIRONMENTAL PROTECTION <b>DIVISION</b>